VIGOUREUX, Martin [FR/FR]; 65, rue de l'Abbe Groult, F-75015 Paris (FR). DOUVILLE, Richard [FR/FR]; Appartement 31, 5, rue Pierre Mendes France, F-91220 Bretigny sur Orge (FR). DOTARO, Emmanuel [FR/FR]; 14, Résidence du Clos, F-91370 Verrières le Buisson (FR). CIAVAGLIA, Laurent [FR/FR]; 94, rue Babillot, F-75013 Paris (FR).
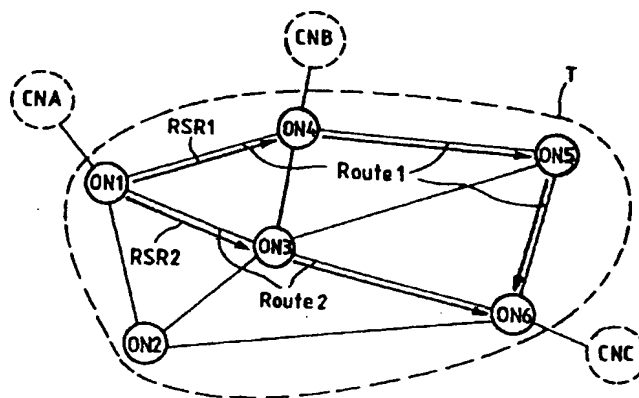
(54) Title: METHOD OF DETERMINING A SPECTRAL ROUTE FOR A GIVEN CONNECTION IN AN OPTICAL TELECOMMUNICATION NETWORK

(54) Titre : PROCEDE POUR DETERMINER UNE ROUTE SPECTRALE POUR UNE CONNEXION DONNE DANS UN RESEAU DE TELECOMMUNICATION OPTIQUE

(57) Abstract: The invention relates to a method of determining a spectral route for a given connection in an optical telecommunication network (T) between a start node (ON1) and an end node (ON6) of said network. The inventive method consists in: using a standard routing method to determine one or more spatial candidate routes (Route 1, Route 2) which connect the start node (ON1) and the end node (ON6), whereby each spatial candidate route (i) comprises a series of route segments, which each link two network nodes directly, and (ii) can support several spectral routes; sending a route establishment request message from the start node (ON1) to the end node (ON6); collecting values of parameters from this message as it passes through each node along said spatial candidate route, e.g. the transparency parameter which characterises the spectral dimension (availability of wavelengths, physical parameters varying according to the blocking of links, etc); and, subsequently, using an optimisation method to process all of the parameter values thus collected in order to determine a spectral route, with the selection of one spatial route from the spatial candidate routes if several exist.

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A METHOD OF DETERMINING A SPECTRAL ROUTE FOR A GIVEN
CONNECTION IN AN OPTICAL TELECOMMUNICATIONS NETWORK

The invention relates to a method of determining a
spectral route for a given connection in an optical

5   telecommunications network, and it also relates to a node
for implementing the method. It relates more
particularly to wavelength division multiplex (WDM)
optical networks that use a plurality of wavelengths to
transmit a plurality of data streams simultaneously on

10   the same optical fibre.

To set up a connection in this kind of network, it
is necessary to determine not only a spatial route,
consisting of a sequence of route segments connecting the
starting node to the destination node, but also a

15   spectral route, since each segment is able to support a
plurality of wavelengths each constituting a spectral
route segment. Selecting a spectral route entails
selecting the wavelength to be used, or the wavelengths
to be used successively, on different segments along the

20   spatial route. It is sometimes necessary to carry out
operations on the signal and/or the information
transported, necessitating the addition of dedicated
equipment to the network and the use thereof. However,
such processing operations are costly, and it is

25   therefore desirable to avoid them as much as possible.
They may relate to regeneration and/or wavelength
conversion, which may be carried out by purely optical
means or using optical-electrical and electrical-optical
conversion means.

30   The expression "wavelength continuity" refers to the
use of the same wavelength from the starting node to the
destination node, even if operations on the signal and/or
the information transported require optical-electronic-
optical conversion or 1R, 2R, or 3R regeneration.

35   The term "transparency" is used, a distinction being
drawn between different types of transparency, depending
on whether optical-electronic-optical conversion,

wavelength conversion, 1R, 2R or 3R regeneration, or a combination of these operations are avoided. The aim is to avoid the route for the signal passing through "non-transparency points" or, if this is not possible, to

5   minimize the number of non-transparency points the signal passes through. For example, in the case of a form of transparency consisting in the absence of optical-electronic-optical conversion, the aim is to minimize the number of times the optical signal passes through opto-

10   electronic and electronic-optical interfaces. If it is not possible to avoid conversion completely, then a route is looked for that minimizes the number of conversions needed.

There may additionally be connection capacity

15   constraints or quality-of-service constraints that influence the selection of the spatial route and the spectral route.

At present, there is no satisfactory method of determining a transparent route of the above kind. One

20   method was proposed to the IETF in Generalized MPLS – Signaling Functional Description, chapters 3.4 and 3.5, Expiration date: November 2001, Network Working Group, Internet Draft, URL = http://search.ietf.org/internet-drafts/draft-ietf-mpls-generalized-signaling-07.txt.

25   That prior art method consists in:

- using a conventional routing method to determine a spatial route connecting a starting node to a destination node and comprising a sequence of route segments, each segment interconnecting two nodes of the network

30   directly;

- determining a first set of wavelengths, in the starting node, for communicating with the next node constituting the route, i.e. the second node on the route;

35   - determining, from the set of wavelengths proposed by the preceding node, a second set of wavelengths, in the second node, for communicating with the next node

constituting the route, i.e. the third node on the route;

- in the nth node, determining, from the set of wavelengths proposed by the preceding node, an $(n+1)^{th}$ set

5 of wavelengths, for communicating with the next node constituting the route, i.e. the $(n+1)^{th}$ node on the route; and so on, as far as the destination node.

The object of the above prior art method is only to assure wavelength continuity. The nodes do not propagate

10 the sets of wavelengths because they do not need to do this to find a spectral route assuring wavelength continuity (should one exist end to end).

Each node of the route may retain or reduce the set of wavelengths that it inherits from the upstream node,

15 according to the resources available for the connection to the downstream node. A transparent route is finally set up if the resulting set contains at least one wavelength. A drawback of that method is a high probability of blocking, since the selection made locally

20 at each node may reduce options in downstream nodes. That method therefore constitutes a sub-optimum solution, or even no solution at all in some cases, when there is in fact an acceptable solution, although it is not transparent end to end. Also, the above prior art method

25 takes account of only one parameter: the continuity of a given wavelength.

The object of the invention is to propose a method that does not have the above drawbacks.

The invention consists in a method of determining a

30 spectral route in an optical telecommunications network between a starting node and a destination node of the network, the method being characterized in that it consists in:

- using a conventional routing method to determine

35 at least one candidate spatial route connecting the starting node to the destination node, each candidate spatial route consisting of a sequence of route segments,

each segment connecting two nodes of the network directly and being adapted to support a plurality of wavelengths each constituting a spectral route segment;

- collecting values of parameters characterizing all
5 the spectral route segments along each candidate spatial route; and

- finally, using an optimization method to process all the collected parameter values to select a spectral route and the spatial route that supports it by selecting
10 the wavelength to be used, or the wavelengths to be used successively, to connect the starting node to the destination node.

The above method has the advantage of reducing the probability of blocking resulting from the impossibility
15 of finding a route, since it provides, at any given time, knowledge of the parameter values for all the segments constituting one or more candidate routes (especially transparency parameter values). This complete knowledge is used to select more efficiently a transparent route or
20 a route comprising a minimum number of non-transparency points. This overview leads to real optimization, i.e. avoiding possible solutions being abandoned during the process.

In a preferred embodiment, to collect parameter
25 values characterizing all route segments along each candidate spatial route, a route set-up request message is sent from the starting node to the destination node and parameter values are collected in the message as it passes through each node along the candidate spatial
30 route.

It should be observed that, in order to maximize the chances of finding a transparent route, this method may be applied several times simultaneously on separate spatial routes to satisfy the same connection set up
35 request.

A preferred embodiment of the method of the invention is implemented in the node at the end of the

route whose setting up has been requested, which is called the destination node.

The method of the invention uses the signaling means of the network to transmit transparency parameter values, providing up-to-date values for each new route set up request.

These parameter values do not relate only to wavelengths, and may relate to all other physical parameters of the connections between the nodes of the network.

In one embodiment, the parameters characterizing all the spectral route segments along each candidate spatial route take account of transparency constraints.

In one embodiment, the parameters characterizing all the spectral route segments along each candidate spatial route take account of connection capacity constraints.

In one embodiment, the parameters characterizing all the spectral route segments along each candidate spatial route take account of quality of service constraints.

The invention also provides an optical network node for implementing a method according to the invention, the node being characterized in that it comprises management means for:

- receiving a route set-up request message on a predetermined spatial route passing through the node;

- adding to the content of the message parameter values concerning spectral routes supported by the spatial route segment immediately upstream and/or downstream of the node on the spatial route, together with parameter values concerning the interfaces of the node; and

- forwarding the message modified in this way to another node situated on the spatial route segment immediately downstream of the node and designated by routing information contained in the message.

The invention will be better understood and other features will become apparent in the light of the

following description and the accompanying drawings, in which:

- Figure 1 shows one example of an optical network in which the method of the invention may be used;

5 - Figure 2 shows the execution of a first portion of the method of the invention in the network example represented in Figure 1; and

- Figure 3 shows the execution of a second portion of the method of the invention in the network example
10 represented in Figure 1.

The network T shown by way of example in Figure 1 comprises optical nodes ON1 to ON6 interconnected by bidirectional or unidirectional connections:.

ON1-ON2
15 ON1-ON3

ON1-ON4

ON2-ON6

ON3-ON5

ON3-ON6

20 In this example, the network T interconnects three client networks CNA, CNB, CNC which are connected to nodes ON1, ON4, ON6, respectively, at the edge of the network T. The method of the invention is executed in the network T and is totally independent of the number
25 and nature of the client networks.

In one implementation of the method of the invention, a connection set-up request CSR is sent by the client network CNA to the management means of the node ON1 in order to set up a connection between the client
30 networks CNA and CNC. The request contains the identity of the requesting client network CNA and the identity of the requested client network CNC and indicates constraints on transparency, capacity, quality of service, etc. The network T must determine a transparent
35 route or, if this is not possible, a route comprising as few points of non-transparency as possible but still conforming to the capacity and quality of service

constraints set for the connection. The optical
transparency parameter constraints may be values of
wavelength, spectral spacing, tolerance of non-linear
effects (four-wave mixing, etc.), the obligatory absence
5   of regeneration, etc.

Figure 2 shows a first portion of this embodiment of
the method of the invention. The management means of the
node ON1 translate the connection set-up request CSR into
a route set-up request RSR, i.e. translate constraints
10   referred to in the connection request into constraints
relating to routing.

Using a conventional routing method, the management
means determine one or more spatial routes, referred to
as candidate routes, connecting the client network CNA to
15   the client network CNC, as a function of the topology and
the connectivity of the network T. For example, they
find two candidate spatial routes, Route 1 and Route 2,
which are valid because they satisfy all the routing
constraints referred to in the original connection set-up
20   request CSR.

Route 1 = ON1, ON4, ON5, ON6
Route 2 = ON1, ON3, ON6

The management means of the node ON1 then forward
the route set-up request RSR to the node ON6, and two
25   copies RSR1 and RSR2 of the request are routed
simultaneously on the two routes Route 1 and Route 2.
The routing along these two routes is controlled by the
management means of the starting node ON1 on furnishing
the request to the signaling means of the network T. The
30   copy RSR1 passes first through the node ON4 on the route
Route 1 and the copy RSR2 passes through the node ON3 on
the route Route 2.

Each node ON1, ON4, ON5 through which the route set-
up request RSR1 passes adds to the content of the request
35   parameter values relating to the route segment
immediately upstream and/or downstream of the node on the
spatial route concerned, together with parameter values

concerning the interfaces of the node, these values
corresponding to parameters referred to in the request,
in particular optical transparency parameters. Each node
ON1, ON3 through which the route set-up request RSR2

5   passes performs the same action on the request RSR2. the
link between ON3 and ON6. These parameter values may
equally relate to the downstream connection and the
upstream connection of the node. Finally, the two copies
RSR1 and RSR2 of the route set-up request reach the

10   destination node ON6.

In a first embodiment, the data collected in these
two copies is processed by the management means of the
destination node ON6 to determine an optimum combination
of spectral route segments between the nodes ON1 and ON6

15   along each of the spatial routes taken by the connection
requests. This data is processed using an optimization
algorithm that minimizes a cost function taking into
account all the parameter values collected. This
algorithm may employ a shortest path algorithm such as

20   the Dijkstra algorithm.

If at least one transparent route is possible, the
optimization algorithm finds a transparent route. If no
transparent route is possible, the optimization algorithm
determines a route comprising the fewest possible points

25   of non-transparency, i.e. an optimum combination of
transparent sub-paths.

Figure 3 represents a second portion of the method
of the invention. After determining the optimum spectral
route in the manner described above, the destination node

30   ON6 sends a route establishment message PEM to the
starting node ON1 and a route set-up request received
acknowledgement message ACK to the next node on the
spatial route that supports the selected spectral route
(Route 2), which is the node ON3 in this example. This

35   message contains a list of the nodes constituting the
route that has been determined, and in this example Route
2 is made up of the nodes ON1-ON3-ON6.

The destination node ON6 sends a route release message RR to all the other immediately adjacent nodes along spatial routes that have not been adopted, in this instance Route 1. In this example, the route release
5   message RR is sent to the node ON5, which forwards it in the direction of the node that was the source of the route set-up request (node ON1).

If the algorithm concludes that no route is possible (even a non-transparent route), the destination node ON6
10   sends a route release message to all of the nodes on the routes Route 1 and Route 2, i.e. the nodes ON1, ON3, ON4, ON5.

In a second embodiment, the two copies RSR1 and RSR2 of the route set-up request (containing all the data
15   collected) are not processed in the destination node ON6, but are returned from the destination node ON6 to the starting node ON1, or to a central unit somewhere in the network T, to be processed there. If the algorithm concludes that no route is possible (even a non-
20   transparent route), the node ON1, respectively the central unit, sends a route release message to all of the nodes situated along the routes Route 1 and Route 2, i.e. the nodes ON1, ON3, ON4, ON5.

The first embodiment has the advantage that it
25   avoids forwarding all of the data collected to the starting node or a central processing unit. This avoids occupying network resources for such forwarding.